Rocky Mountains Southwest Great Plains

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Potential Influences of Horizontal and Vertical Air Movement in Ponderosa Pine Stands on Mountain Pine Beetle Dispersal

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Horizontal and vertical wind speeds were monitored in partially cut and uncut ponderosa pine stands in the Black Hills of South Dakota. Horizontal wind speeds of 2 to 4 mph occurred most frequently while wind speeds above 5 mph were observed <11% of the time. Vertical wind speeds in the partially cut stands were not different than in the uncut stands. Wind direction changed more than 40 times per day. Air movements in relation to mountain pine beetle dispersal and pheromone drift are discussed.

Keywords: Ponderosa pine, air movement, wind speeds, mountain pine beetle

Air movement directly influences the behavior of the mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) by changing its directional dispersal. Beetles fly in all directions at low wind speeds, but Gray et al. (1972) found about 59% flew with the wind. When horizontal winds were less than 3.1 mph, more beetles flew against winds than when wind speeds exceeded 4.7 mph. Although wind speeds prohibiting upwind flight have not been determined, Gray et al. (1972) observed several beetles flying against winds in excess of 4.7 mph but no flight when winds were in excess of 5 to 6 mph.

Air movement indirectly influences MPB behavior through its action on the dispersal of MPB pheromones. Wind creates pheromone plumes of various widths and directions depending on wind speed and direction (Fares et al. 1980). Pheromone plumes are more likely to develop in early morning or late afternoon when air temperatures are more stable and air is less turbulent (Fares et al. 1980). During midday, air is more buoyant and thus more likely to travel vertically than horizontally, thereby carrying pheromones into and above the tree crowns and disrupting MPB pheromone communication below the canopy. However, the linearity of pheromone dispersal is greater when wind speeds are greater (Elkinton et al. 1987).

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Because stand density has been implicated in the regulation of air movement (Schmitz et al. 1989), we examined the horizontal and vertical air movement in ponderosa pine (*Pinus ponderosa* Lawson) to determine the magnitude of differences between lightly stocked and densely stocked stands.

Methods

Wind speed and direction were monitored in two sets of growing stock level (GSL) plots of ponderosa pine about 9 and 15 miles southeast of Lead, South Dakota. These locations are called the Brownsville and Experimental Forest plots, respectively. Plot characteristics of basal area, trees per acre, and average diameter were previously described in Schmid et al. (1991).

To measure horizontal wind speed and direction, standard 3-cup anemometers and directional vanes were operated about 6 feet aboveground in a partially cut stand of GSL 60 and an uncut stand of GSL 150 at the Brownsville location during July 20–27 and July 31-Aug. 2, 1988. One anemometer and one directional vane were operated in the partially cut GSL 80 plot at Brownsville during July 21–24 and August 18–24 and in a partially cut GSL 80 plot on the Experimental Forest during July 10–21 and August 14–18, 1989.

To determine vertical wind speed within a partially cut stand and an uncut stand, 3-dimensional anemom-

eters were operated at 6 feet aboveground in the partially cut stand of GSL 60 and an uncut stand of GSL 150 at Brownsville during July 21–24 and August 18–24, 1989. Three-dimensional anemometers were also operated in a partially cut stand of GSL 40 and an uncut stand of GSL 160 on the Experimental Forest during July 10–21 and August 14–18, 1989. Each 3-dimensional anemometer monitors vertical wind speed with one anemometer and horizontal wind speed with two anemometers—one for the north-south component of the air movement and one for the east-west component.

The 3-cup anemometers and wind vanes were manufactured by Campbell Scientific, Inc.[2] of Logan, Utah. The anemometers have a threshold speed of 1 mph and are accurate to $\pm$ 0.25 mph. The directional vanes also have a threshold sensitivity of 1 mph and are accurate to $\pm$ 5 degrees. The 3-dimensional anemometers were manufactured by the R. M. Young Co.[2] and have a sensitivity threshold of 0.5 mph.

The instruments were operated in late July and August because that time period coincides with the flight period of the MPB in the Black Hills (see Schmid 1972). They were operated in the partially cut stands because these stands represent stocking levels of susceptible-sized trees that commonly exist after partial cutting. The uncut stands represent stocking levels in which MPB infestations commonly develop.

The anemometers were installed as far from adjacent trees as possible to avoid the influence of tree trunks on horizontal wind speed and direction, and the influence of tree crowns on vertical wind speeds. However, anemometers in the uncut stands were within 10 feet of the adjacent trees and were overshadowed by tree crowns because of the stocking.

The instruments were connected via wires to Campbell Scientific, Inc. microloggers[2] which recorded the respective measurements at 15-minute intervals in 1988 and 30-minute intervals in 1989. These intervals were used because other microclimatological data were being collected and the microloggers were programmed to collect all data at one time. The recorded values were instantaneous measurements reflecting the conditions existing at the time of recording; they were not averages for the conditions existing during the interval between recordings.

The frequency of various horizontal wind speeds and directions were derived by summarizing the data. Because MPB emerge and disperse during daylight hours, frequencies of horizontal air speeds and directions are expressed for 0600 to 1900 h, Mountain Daylight Time (MDT). A change in wind direction was considered to have occurred when two successive recordings differed by 10 or more degrees. To determine whether vertical wind speeds (both upward and downward) were significantly different between GSLs, wind speed measurements from each GSL with 3-dimensional anemometers were subjected to an analysis of variance with time of day as a repeated measure and days treated as replicates, = 0.05. Because air movement appeared to vary at different times of the day, vertical wind speeds in the time periods 0600–1000, 1030–1430 and 1500–1900 h were each subjected to the analysis of variance.

[2]The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Results and Discussion

Horizontal Wind Speed

Wind speeds of >2 to 4 mph occurred most frequently in all stands except the uncut stand of GSL 150 in 1988 (fig. 1). In this GSL operational difficulties with the micrologger allowed data to be collected for only 2 days, so the associated paucity of data may have distorted the frequencies of the different speeds. Wind speeds greater than 5 mph occurred less than 11% of the time.

In relation to MPB dispersal, wind speeds greater than or equal to 5 mph would be expected to change omni-directional MPB dispersal to the downwind direction of the prevailing wind. Based on our frequencies of winds greater than 5 mph, omni-directional dispersal would rarely be changed to predominantly one direction.

Vertical Wind Speed

Vertical wind speeds in the partially cut stands of GSL 40 on the Experimental Forest and of GSL 60 at Brownsville were not significantly different from vertical wind speeds for their respective uncut stands during any of the three time periods. Upward wind speeds did not exceed 2 mph in either the partially cut or uncut stands at either location in 1989 (fig. 2). Downward wind speeds exceeded 2 mph in only the partially cut stand of GSL 40 on the Experimental Forest in 1989.

Insignificant differences in vertical wind speeds between the partially cut and uncut stands suggest that vertical winds are not disrupting the horizontal movement of MPB pheromones in the partially cut stands any more than in uncut stands. Any disruption is probably caused by convection currents created by the greater heating below the canopy of partially cut stands of low GSL, as reported in Schmid et al. (1991).

Wind Direction

Wind direction changed an average of 37 times/day in the Brownsville plot and 40 times/day in the Experimental plot in 1989. In 1988 when wind direction was monitored every 15 minutes, wind changed direction at least 70 times/day. During daylight hours, wind direction was seldom constant for more than 2 hours. Considering the influence of variable wind direction on pheromone dispersion (Elkinton et al. 1987), a pheromone plume would be sustained in any particular direction for not more than 2 hours and usually for a lesser time period. Further, a pheromone plume as diagrammed by Fares et al. (1980) would develop only under special circumstances and infrequently during the MPB dispersal period. Assuming a tree under attack

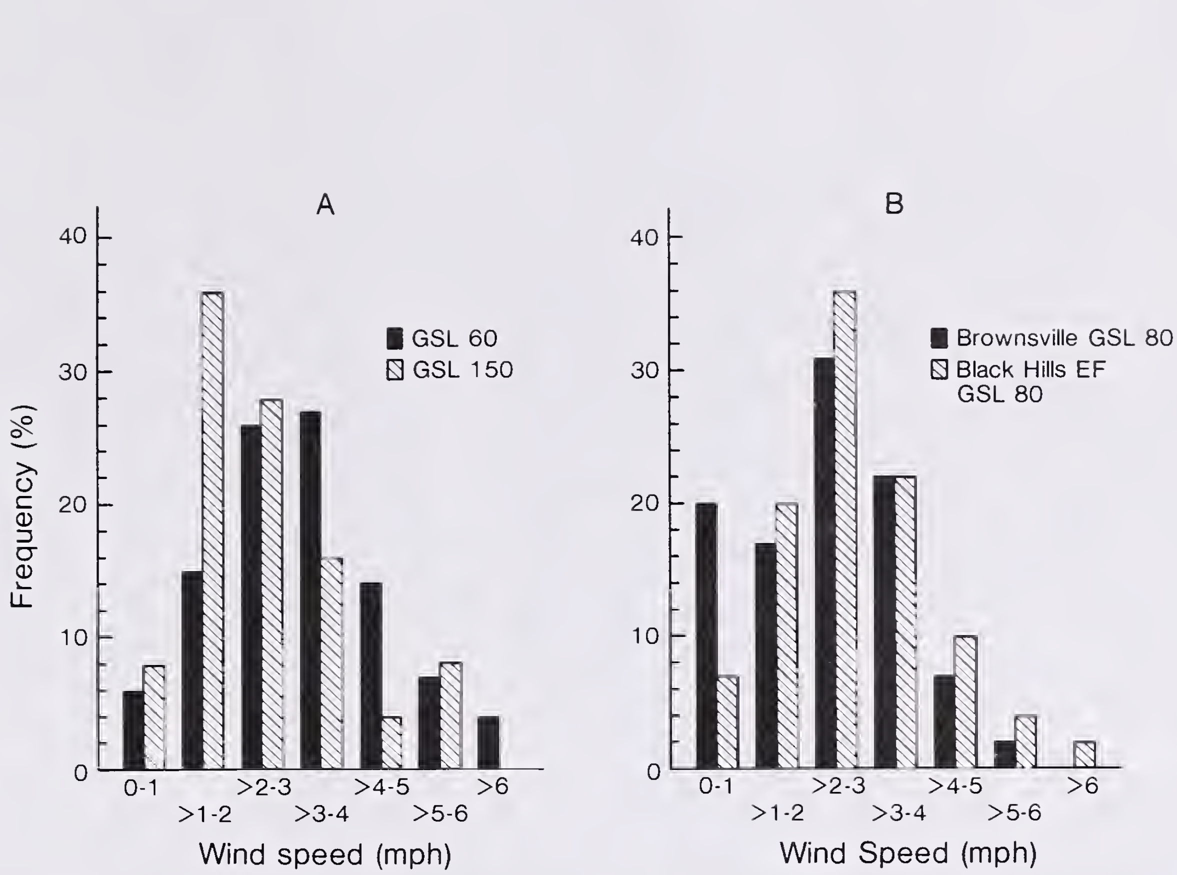

Figure 1.—Frequency (%) of horizontal wind speeds during 0600 to 1900 h MDT for (A) Brownsville GSL 60 and 150 plots in 1988 and (B) Brownsville and Experimental Forest GSL 80 plots in 1989.

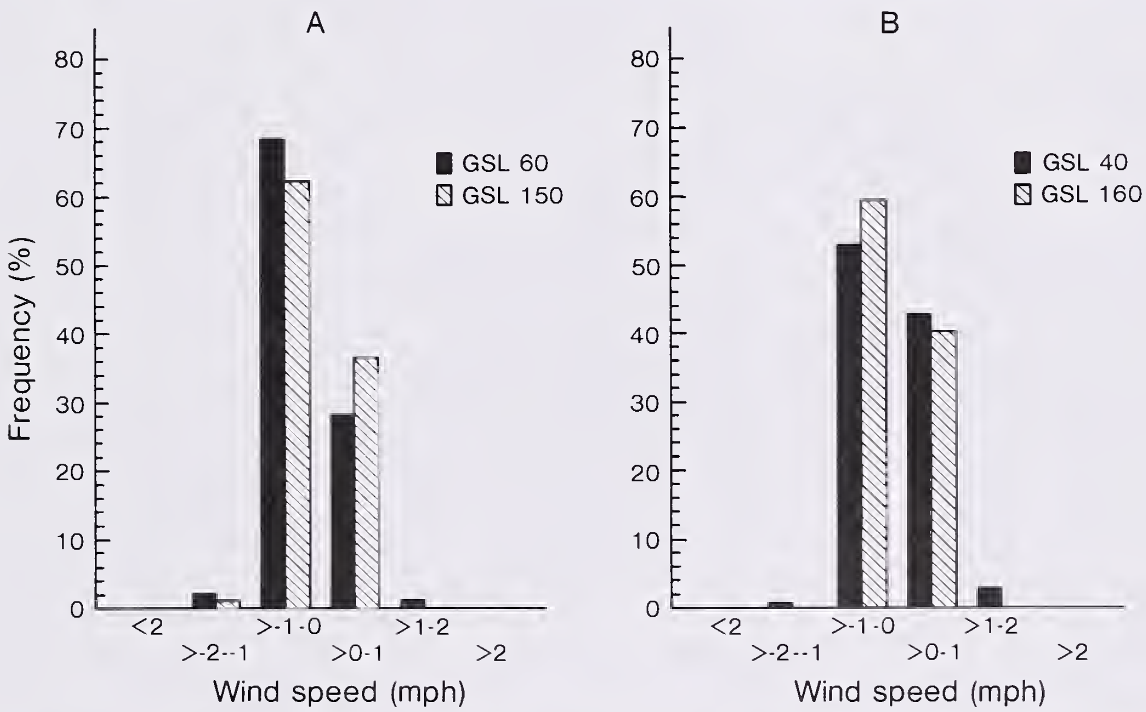

Figure 2.—Frequency (%) of vertical wind speeds during 0600 to 1900 h MDT in various growing stock levels of ponderosa pine in 1989 for (A) Brownsville GSL 60 and 150 (control) and for (B) Experimental Forest GSL 40 and 160 (control). Plus values indicate upward air movement; minus values indicate downward air movement.

emits pheromones throughout the day, the frequently changing winds would drift the pheromones in a wide arc, the extent of the arc depending on the angle formed by the extremes of wind direction. On days when the wind originated from predominantly one direction, the pheromone drift may more closely approximate a plume. However, the majority of the time, pheromone drift would fan out and not resemble the Gaussian plume as diagrammed by Fares et. al (1980). Conceivably, pheromones drifting in one direction could be redirected in the opposite direction by subsequent changes in wind of 180° and thus be intermixed with pheromones emitted after the change in wind direction.

Because MPB change their dispersal direction in response to changes in wind direction, and wind direction changes frequently during the day (Gray et al. 1972, our data), the "spot containment" strategy for holding MPB in situ must place tree baits on at least opposite sides of each spot infestation if the strategy is to effectively contain all dispersing MPB.

Despite the fact that wind direction changes frequently within a stand, specific locations have prevailing winds from general directions. For example, the Brownsville GSL 80 had winds predominantly from a northerly or southeasterly direction (table 1). The Experimental Forest GSL 80 stand had prevailing winds from the

Table 1.—Frequency (%) of winds from specific directions in GSL 80 plots during 0600 to 1900 h MDT in July and August 1989.

Wind direction (degrees)	Brownsville (%)	Black Hills Expt. For. (%)
0–45°	12.5	19.6
46–90°	7.8	28.9
91–135°	6.3	13.2
136–180°	16.5	6.7
181–225°	22.0	9.1
226–270°	12.5	8.2
271–315°	5.9	7.0
316–360°	16.5	7.3

northeasterly to easterly direction. The use of tree baits at each of these locations would be more successful if one of the baits was placed on the upwind side of the infested spot, assuming of course that susceptible-sized trees exist in that direction.

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